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Research Article

A new *Boulenophrys* species (Anura, Megophryidae) from the coastal hills of eastern Fujian Province, China

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Abstract

A new species of the genus *Boulenophrys* is described from the coastal hills of eastern Fujian Province, China. The new taxon can be distinguished from all recognized congeners by a combination of discrete morphological character state differences and genetic divergences in the combined mitochondrial 16S + CO1 genes. We also provide a map showing the distribution pattern of *Boulenophrys* species in Fujian and a provincial-specific key, which will aid their conservation by helping the local authorities accurately identify species during field identifications and data collection efforts.

Key words: *Boulenophrys lichun* sp. nov., conservation actions, distribution pattern, diversity, Horned Toads, identification, new species, provincial key, taxonomy

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Introduction

The Chinese Horned Toads (*Boulenophrys* Fei, Ye & Jiang, 2016) comprise 68 recognized species which are classified within the subfamily Megophryinae (Bonaparte, 1850) (Lyu et al. 2023; Zeng et al. 2024; Wang et al. 2024). They are widespread in the subtropical and tropical areas of mainland East Asia, mostly in southern China and southwards into northernmost Indochina, including Vietnam, Laos, Myanmar, and Thailand (Fei and Ye 2016; Lyu et al. 2023; Frost 2024). Located in southeastern China, Fujian Province possesses a complex mountain system. Its *Boulenophrys* diversity is still underestimated with three of the five species known from the area only described in recent years (Messenger et al. 2019; Lyu et al. 2021). Inger and Romer (1961) included a paratype of *B. brachykolos* (Inger & Romer, 1961) from Fujian, which may be a misidentification of *B. ombrophila* (Messenger & Dahn, 2019) due to morphological similarity (Lyu et al. 2023). Lyu et al. (2023) also restricted *B. brachykolos* to Hong Kong and Shenzhen in the east of the Pearl River Estuary based on voucher specimens and molecular data. Thus, only five recognized species occur in Fujian, namely *B. boettgeri* (Boulenger, 1899), *B. daiyunensis* (Lyu, Wang & Wang, 2021), *B. kuatunensis* (Pope, 1929), *B. ombrophila*, and *B. sanmingensis* (Lyu & Wang, 2021).

During recent field surveys in eastern Fujian, we collected a series of *Boulenophrys* specimens (Fig. 1). Preliminary morphological examination indicated that they could be distinguished from recognized congeners by a series of discrete

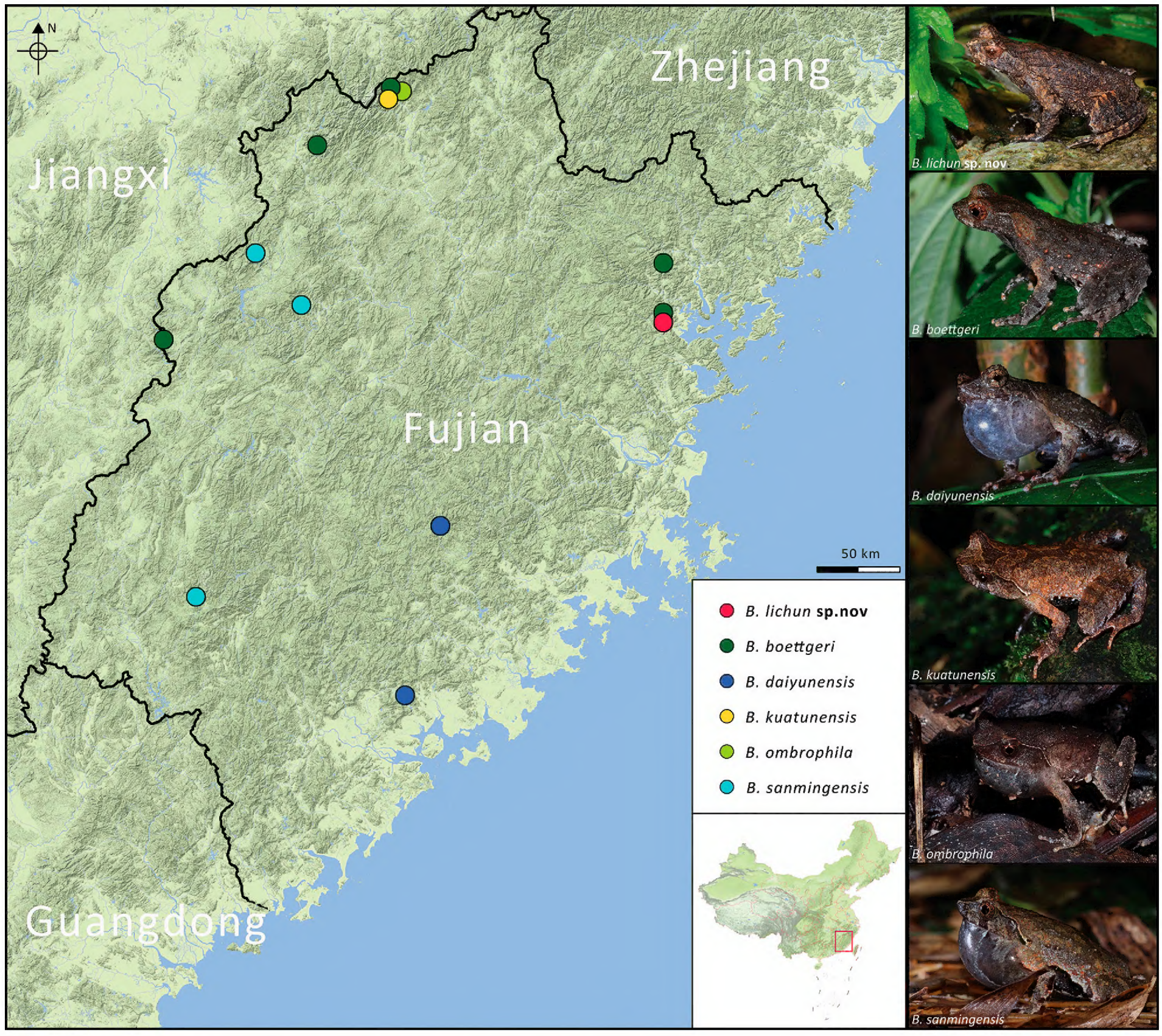

Figure 1. Map showing the distribution pattern of *Boulenophrys* species in Fujian Province, China. Distribution sites accessed from Lyu et al. (2023).

characters. Subsequent molecular analysis further revealed that these specimens represent a separate evolutionary lineage, displaying significant divergence from known congeners. Thus, we describe them as a new species below.

Materials and methods

Morphology

All examined specimens were fixed in 10% buffered formalin and later transferred to 70% ethanol. All studied specimens have been deposited at the Guangdong Polytechnic of Environmental Protection Engineering (GEP), Foshan City, Guangdong, and the Herpetological Museum, Chengdu Institute of Biology, the Chinese Academy of Sciences (CIB), Chengdu City, China.

External measurements were recorded with a digital caliper (Neiko 01407A stainless steel 6-inch digital caliper) to the nearest 0.1 mm. These measurements are as follows: SVL (snout–vent length, from tip of snout to posterior mar-

gin of vent); HDL (head length, from tip of snout to the articulation of the jaw); HDW (head width, head width at the commissure of the jaws); SNT (snout length, from tip of snout to the anterior corner of the eye); IND (internasal distance, distance between nares); IOD (interorbital distance, minimum distance between upper eyelids); ED (eye diameter, from the anterior corner of the eye to posterior corner of the eye); TD (tympanum diameter, horizontal diameter of tympanum); TED (tympanum–eye distance, from anterior edge of tympanum to posterior corner of the eye); HND (hand length, from the proximal border of the outer palmar tubercle to the tip of digit III); RAD (forearm or radiulna length, from the flexed elbow to the proximal border of the outer palmar tubercle); FTL (foot length, from distal end of shank to the tip of digit IV); TIB (crus or tibiofibula length, from the outer surface of the flexed knee to the heel). Sex was determined by external secondary sexual characters, such as the presence of vocal sacs, nuptial pads, or spines in males and their absence in females (Fei et al. 2009).

Morphological characters of all 68 recognized species of the genus *Boulenophrys* used for comparisons were based on information available in the literature (Table 1).

Table 1. Literature for morphological characters of 68 recognized species of *Boulenophrys*.

***Boulenophrys* species**	**References**
B. acuta (Wang, Li & Jin, 2014)	Li et al. 2014; Lyu et al. 2023
B. angka (Wu, Suwannapoom, Poyarkov, Pawangkhanant, Xu, Jin, Murphy & Che, 2019)	Wu et al. 2019
B. anlongensis (Li, Lu, Liu & Wang, 2020)	Li et al. 2020; Lyu et al. 2023
B. baishanzuensis (Wu, Li, Liu, Wang & Wu, 2020)	Wu et al. 2020
B. baolongensis (Ye, Fei & Xie, 2007)	Ye et al. 2007; Fei and Ye 2016
B. binchuanensis (Ye & Fei, 1995)	Lyu et al. 2023
B. binlingensis (Jiang, Fei & Ye, 2009)	Fei et al. 2009; Lyu et al. 2023
B. boettgeri (Boulenger, 1899)	Lyu et al. 2023
B. brachykolos (Inger & Romer, 1961)	Lyu et al. 2023
B. caobangensis (Nguyen, Pham, Nguyen, Luong & Ziegler, 2020)	Nguyen et al. 2020
B. caudoprocta (Shen, 1994)	Shen 1994; Lyu et al. 2023
B. congjiangensis (Luo, Wang, Wang, Lu, Wang, Deng & Zhou, 2021)	Luo et al. 2021; Lyu et al. 2023
B. cheni (Wang & Liu, 2014)	Wang et al. 2014; Lyu et al. 2023
B. chishuiensis (Xu, Li, Liu, Wei & Wang, 2020)	Lyu et al. 2023
B. daiyunensis (Lyu, Wang & Wang, 2021)	Lyu et al. 2021; Lyu et al. 2023
B. daoji (Lyu, Zeng, Wang & Wang, 2021)	Lyu et al. 2021; Lyu et al. 2023
B. daweimontis (Rao & Yang, 1997)	Rao and Yang 1997
B. dongguanensis (Wang & Wang, 2019)	Lyu et al. 2023
B. elongata Zeng, Wang, Chen, Xiao, Zhan, Li & Lin, 2024	Zeng et al. 2024
B. fengshunensi Wang, Zeng, Lyu & Wang, 2022	Lyu et al. 2023
B. fanjingmontis (Zhang, Liang, Ran & Shen, 2012)	Lyu et al. 2023
B. fansipanensis (Tapley, Cutajar, Mahony, Nguyen, Dau, Luong, Le, Nguyen, Nguyen, Portway, Luong & Rowley, 2018)	Tapley et al. 2018a
B. frigida (Tapley, Cutaja, Nguyen, Portway, Mahony, Nguyen, Harding, Luong & Rowley, 2021)	Tapley et al. 2021
B. hoanglienensis (Tapley, Cutajar, Mahony, Nguyen, Dau, Luong, Le, Nguyen, Nguyen, Portway, Luong & Rowley, 2018)	Tapley et al. 2018a

***Boulenophrys* species**	**References**
B. hungtai Wang, Zeng, Lyu, Xiao & Wang, 2022	Lyu et al. 2023
B. hengshanensis Qian, Hu, Mo, Gao, Zhang & Yang, 2023	Qian et al. 2023
B. insularis (Wang, Liu, Lyu, Zeng & Wang, 2017)	Wang et al. 2017a; Lyu et al. 2023
B. jiangi (Liu, Li, Wei, Xu, Cheng, Wang & Wu, 2020)	Lyu et al. 2023
B. jingdongensis (Fei & Ye, 1983)	Fei et al. 1983; Lyu et al. 2023
B. jinggangensis (Wang, 2012)	Wang et al. 2012; Lyu et al. 2023
B. jiulianensis (Wang, Zeng, Lyu & Wang, 2019)	Lyu et al. 2023
B. kuatunensis (Pope, 1929)	Lyu et al. 2023
B. leishanensis (Li, Xu, Liu, Jiang, Wei & Wang, 2018)	Lyu et al. 2023
B. lushuiensis (Shi, Li, Zhu, Jiang, Jiang & Wang, 2021)	Wang et al. 2017b; Lyu et al. 2023
B. liboensis (Zhang, Li, Xiao, Li, Pan, Wang, Zhang & Zhou, 2017)	Zhang et al. 2017
B. lini (Wang & Yang, 2014)	Wang et al. 2014; Lyu et al. 2023
B. lishuiensis (Wang, Liu & Jiang, 2017)	Lyu et al. 2023
B. minor (Stejneger, 1926)	Lyu et al. 2023
B. mirabilis (Lyu, Wang & Zhao, 2020)	Lyu et al. 2020; Lyu et al. 2023
B. mufumontana (Wang, Lyu & Wang, 2019)	Lyu et al. 2023
B. nankunensis (Wang, Zeng & Wang, 2019)	Lyu et al. 2023
B. nanlingensis (Lyu, Wang, Liu & Wang, 2019)	Lyu et al. 2023
B. obesa (Wang, Li & Zhao, 2014)	Li et al. 2014; Lyu et al. 2023
B. ombrophila (Messenger & Dahn, 2019)	Lyu et al. 2023
B. omeimontis (Liu, 1950)	Lyu et al. 2023
B. palpebralespinosa (Bourret, 1937)	Fei et al. 2009; Lyu et al. 2023
B. pepe (Wang & Zeng, 2024)	Wang et al. 2024
B. puningensis Wang, Zeng, Lyu, Xiao & Wang, 2022	Lyu et al. 2023
B. qianbeinsis (Su, Shi, Wu, Li, Yao, Wang & Li, 2020)	Lyu et al. 2023
B. rubrimera (Tapley, Cutajar, Mahony, Chung, Dau, Nguyen, Luong & Rowley, 2017)	Tapley et al. 2017, 2018b
B. sangzhiensis (Jiang, Ye & Fei, 2008)	Lyu et al. 2023
B. sanmingensis (Lyu & Wang, 2021)	Lyu et al. 2021; Lyu et al. 2023
B. shimentaina (Lyu, Liu & Wang, 2020)	Lyu et al. 2020; Lyu et al. 2023
B. shuichengensis (Tian & Sun, 1995)	Tian and Sun 1995; Tian et al. 2000; Fei and Ye 2016
B. shunhuangensis (Wang, Deng, Liu, Wu & Liu, 2019)	Wang et al. 2019b; Lyu et al. 2023
B. spinata (Liu & Hu, 1973)	Hu et al. 1973; Lyu et al. 2023
B. tongboensis (Wang & Lyu, 2021)	Lyu et al. 2021; Lyu et al. 2023
B. tuberogranulatus (Shen, Mo & Li, 2010)	Mo et al. 2010; Fei and Ye 2016; Lyu et al. 2023
B. wugongensis (Wang, Lyu & Wang, 2019)	Lyu et al. 2023
B. wuliangshanensis (Ye & Fei, 1995)	Lyu et al. 2023
B. wushanensis (Ye & Fei, 1995)	Ye and Fei 1995; Fei and Ye 2016; Lyu et al. 2023
B. xiangnanensis (Lyu, Zeng & Wang, 2020)	Lyu et al. 2020; Lyu et al. 2023
B. xianjuensis (Wang, Wu, Peng, Shi, Lu & Wu, 2020)	Lyu et al. 2023
B. xuefengmontis Lyu & Wang, 2023	Lyu et al. 2023
B. yangmingensis (Lyu, Zeng & Wang, 2020)	Lyu et al. 2020; Lyu et al. 2023
B. yaoshanensis Qi, Mo, Lyu, Wang & Wang, 2021	Qi et al. 2021; Lyu et al. 2023
B. yingdeensis Qi, Lyu, Wang & Wang, 2021	Qi et al. 2021; Lyu et al. 2023
B. yunkaiensis Qi, Wang, Lyu & Wang, 2021	Qi et al. 2021; Lyu et al. 2023

Phylogeny

We use two partial mitochondrial genes, the 16S ribosomal RNA (16S) and the cytochrome *c* oxidase 1 (COI), for phylogenetic analysis. DNA extraction, PCR amplification, and sequencing protocols follow that of Liu et al. (2018). In total, 84 sequences were used in this study, including six new ones from this study and 78 attained from GenBank. Two samples of the genus *Xenophrys* were used as outgroups (Suppl. material 1).

We used Clustal X 2.0 (Thompson et al. 1997) for sequence aligning with default parameters. PartitionFinder (Lanfear et al. 2012) was used for searching the optimal partitioning schemes and the analysis determined that partitioning by gene was optimal for 16S, while partitioning by codon position was optimal for COI, with GTR+I+G identified as the best-fit nucleotide substitution model for all partitions. Phylogenetic trees were constructed using maximum likelihood (ML) implemented in RaxmlGUI v.1.3 (Silvestro and Michalak 2012), and Bayesian inference (BI) using MrBayes v.3.2.4 (Ronquist et al. 2012). For the ML analysis, an optimal tree was obtained and branch supports were evaluated with 1000 rapid bootstrapping replicates. For the BI analysis, two independent runs were conducted with each running for 10,000,000 generations and sampled every 1000 generations with the first 25% samples discarded as burn-in, resulting in a potential scale reduction factor (PSRF) of < 0.01. Then the remaining trees were used to create a consensus tree. Nodes having ML bootstrap values (BS) ≥ 70 and BI posterior probabilities (BPP) ≥ 0.90 were considered well supported.

Results

The BI and ML phylogenetic trees resulted in essentially identical topologies, with the ML phylogenetic tree shown in Fig. 2. The relationship among the *Boulenophrys* species in our trees correspond to those in previous studies (Liu et al. 2018; Lyu et al. 2023; Zeng et al. 2024; Wang et al. 2024). Our results show that all samples from eastern Fujian, China, cluster into a monophyletic group with strong nodal support (BS 100, BPP 1.00), and are distinct from all known *Boulenophrys* species occurring in Fujian. Furthermore, the corresponding specimens of the evolving lineage can be distinguished from all recognized congeners by a combination of morphological characters. As both the phylogenetic results and morphological comparisons support that the lineage from eastern Fujian represents an undescribed new species, we thus describe it below.

Taxonomic account

***Boulenophrys lichun* sp. nov.**

https://zoobank.org/02303B1E-ED1A-482B-8BD3-B32BC0DB9D6B

Fig. 3

Lichun Horned Toad (in English) / lì chūn jiǎo chán (立春角蟾 in Chinese)

Material examined. *Holotype.* China • ♂; Fujian Province, Ningde City, Jiaocheng District, Mt Nanji; 26.645774°N, 119.519939°E, ca. 230 m elev.; 4 Feb. 2024; Jian Wang, Zhao-Chi Zeng, Shi-Shi Lin and Yuan-Hang Li leg.; GEP a214.

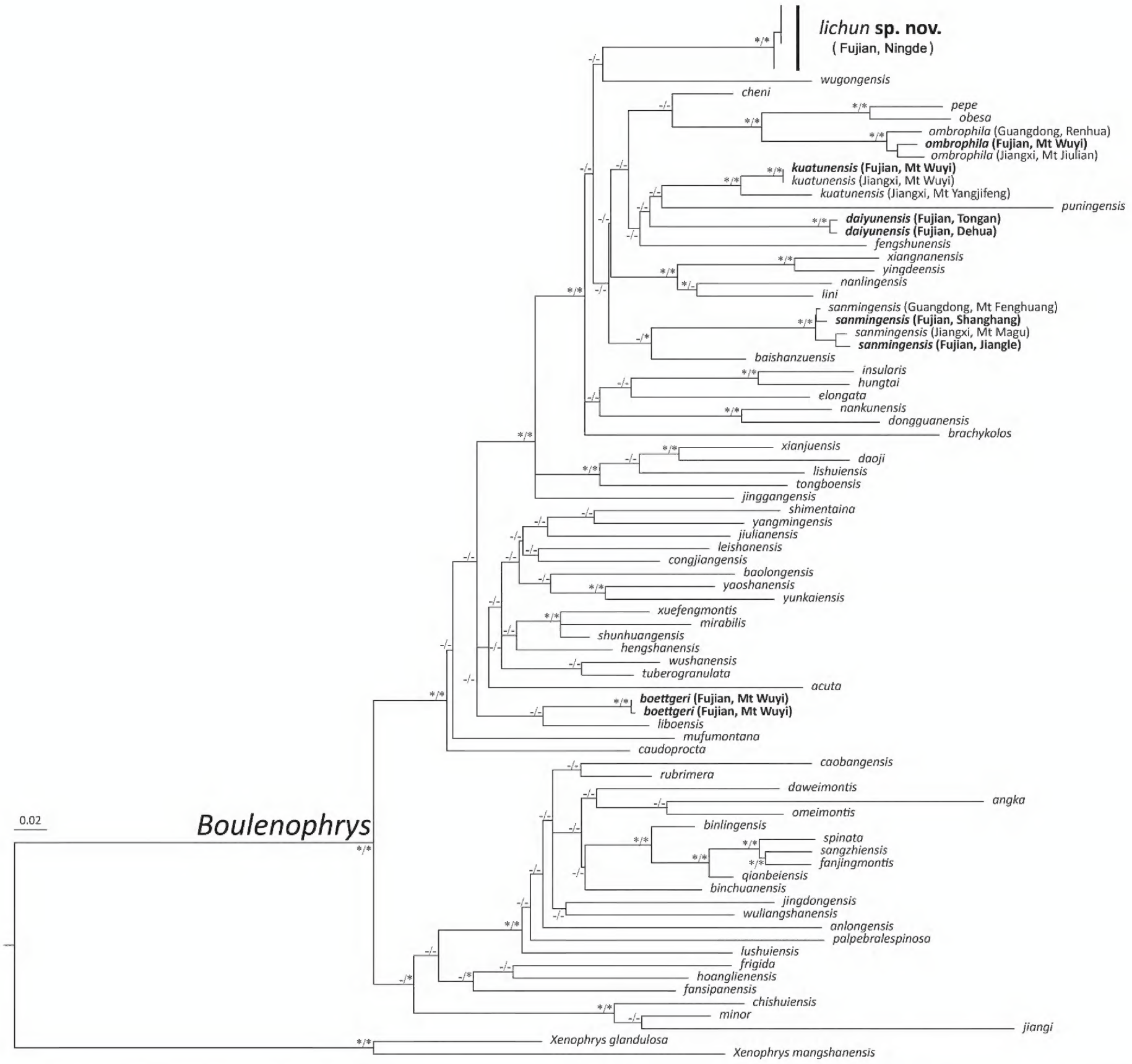

Figure 2. Maximum-likelihood phylogenies, with '*' representing BS ≥ 70 or BPP ≥ 0.90 and '-' representing BS < 70 or BPP < 0.90.

Paratypes. CHINA • 4♂♂; same data as for holotype; CIB 121428 [field number GEP a210], GEP a211–213 • 1♀; same data as for holotype; GEP a215.

Etymology. The specific name *lichun* is derived from Chinese Pinyin Lì Chūn, i.e. 立春 in Chinese, which means the beginning of spring, the first of the 24 solar terms (24节气) of China. The specific name refers to the breeding season of the new species which begins around this period. The song of the new species heralds the spring of a year. The type specimens of the new species were also collected on "Lichun" of the Year 2024.

Diagnosis. (1) small size (SVL 33.5–37.0 mm in five adult males, SVL 47.1 mm in a single adult female); (2) canthus rostralis well developed, tongue not notched posteriorly; (3) tympanum distinct; (4) vomerine ridges and vomerine teeth present; (5) dorsal skin rough and highly granular, discontinuous X-shaped ridge on center of dorsum, discontinuous dorsolateral ridges present, sparse large tubercles on flanks, dorsal limbs with discontinuous transverse ridges and tubercles, ventral skin with dense raised tubercles; (6) outer margin

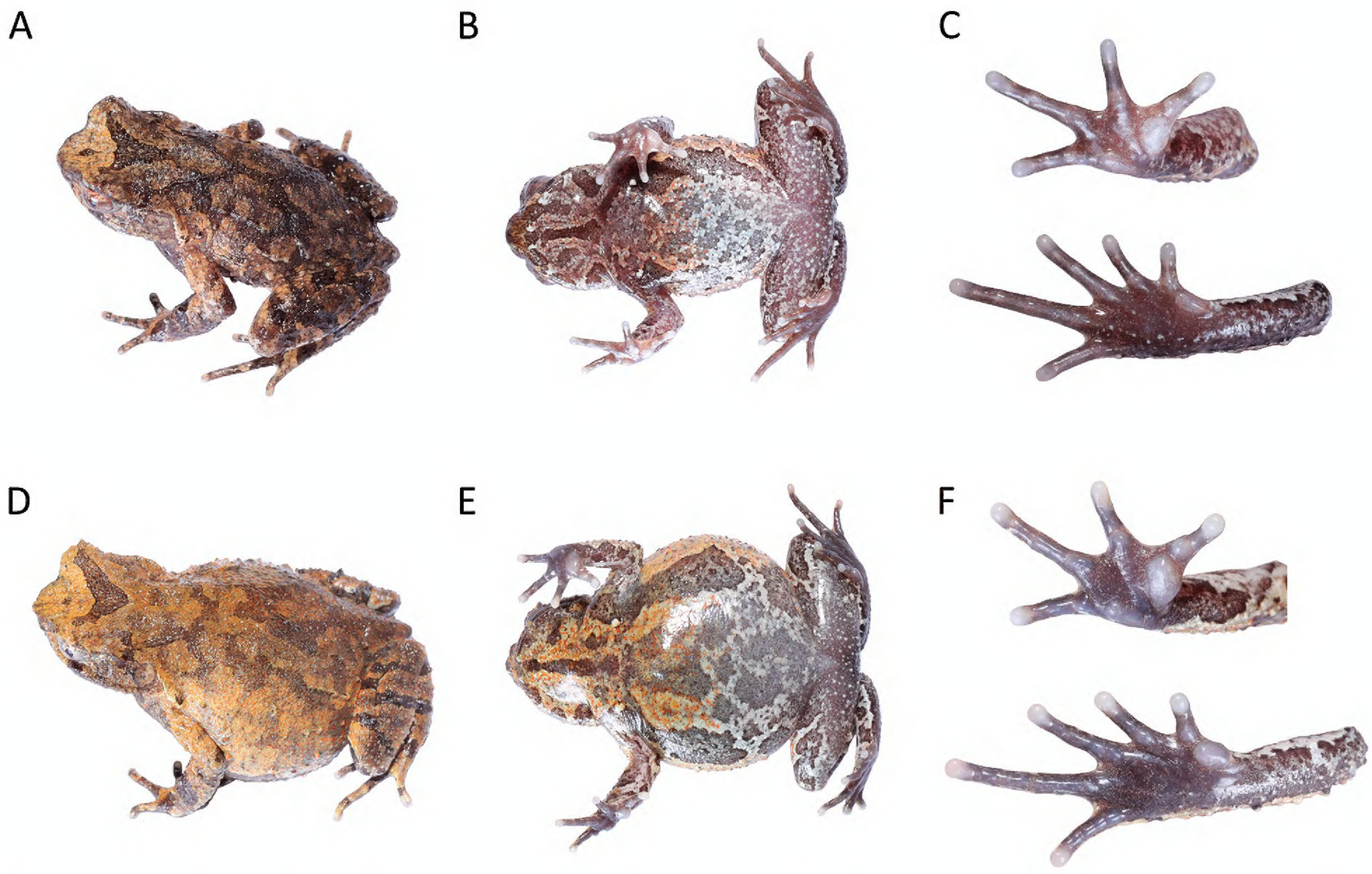

Figure 3. The male holotype (GEP a214, **A–C**) and the female paratype (GEP a215, **D–F**) of *Boulenophrys lichun* sp. nov. in life.

of upper eyelid with a small horn-like prominent tubercle, supratympanic fold distinct and narrow, curving posteroventrally to above arm; (7) two metacarpal tubercles distinct, inner one observably enlarged; relative finger lengths I < II < IV < III; distinct subarticular tubercle at base of each finger; (8) heels not meeting when hindlimbs folded; tibio-tarsal articulation reaching shoulder to posterior corner of eye; (9) toes without webbing and lateral fringes, inner metatarsal tubercle long ovoid, outer one absent, relative toe length I < II < V < III < IV; (10) dorsal surface yellowish-brown with irregular dark-brown patches, and dark-brown triangular marking between eyes, dorsal limbs and digits light brown with dark-brown transverse bands; and (11) dense nuptial spines on dorsal bases of fingers I and II in breeding adult males, subgular vocal sac present in males.

Description of holotype. Adult male. Body size small, SVL 37.0 mm. Head width larger than head length, HWD/HDL 1.04; snout rounded in dorsal view, projecting, sloping backward to mouth in profile, protruding well beyond margin of lower jaw; top of head flat; eyes moderate in size, ED 0.34 of HDL, pupil vertical, near diamond-shaped; nostril obliquely ovoid; canthus rostralis well developed; loreal region slightly oblique; internasal distance slightly larger than interorbital distance; tympanic region oblique, tympanum distinct and visible in dorsal view; tympanum moderate in size, margin clear, upper margin in contact with supratympanic fold, lower margin in contact with upper lip, TD/ED 0.55; large ovoid choanae at base of maxilla; vomerine ridge and vomerine teeth present, maxillary teeth present; margin of tongue rounded, not notched distally; presence of single subgular vocal sac.

Forearm length 0.23 of SVL, hand 0.24 of SVL; webbing absent between fingers, lateral fringes absent, relative finger length I < II < IV < III; tips of fingers slightly dilated, round; subarticular tubercles on base of fingers present, dis-

tinct; inner metacarpal tubercle observably enlarged, outer one slightly smaller; single nuptial pad bearing nuptial spines present on dorsal surface of first and second fingers, respectively. Hindlimbs short, tibio-tarsal articulation reaching forward to posterior conner of eye when hindlimb stretched along body; heels not meeting when flexed hindlimbs held at right angles to body axis; crus length 0.40 of SVL and foot length 0.58 of SVL; relative toe length I < II < V < III < IV; tips of toes round and slightly dilated; toes without lateral fringes and webbing; subarticular tubercles on base of toes present and distinct; inner metatarsal tubercle long ovoid and lacking outer metatarsal tubercle.

Dorsal skin rough and highly granular; dense large tubercles on flanks; single horn-like prominent tubercle on edge of upper eyelid; obvious supratympanic fold curving posteroventrally from posterior corner of eye to level above insertion of arm; upper lip, mandibular articulation, loreal, temporal region excluding tympanum, upper eyelid and surface around cloaca with conical tubercles; discontinuous X-shaped ridge on center of dorsum, discontinuous dorsolateral ridges present; ventral surface with dense raised tubercles; tubercles on ventral hindlimbs and around cloaca bearing tiny spines on their tips; small and distinct pectoral gland closer to axilla; single femoral gland positioned on posterior surface of thigh at midpoint between knee and cloaca.

Coloration of holotype. In life, dorsal surface of body yellowish-brown with irregular dark-brown patches, dark-brown X-shaped marking on center of dorsum, dark-brown triangular marking between eyes. A vertical dark-brown band present below eye. Dorsal surface of limbs with dark-brown transverse bands. Tubercles on edge of upper eyelids orange. Supratympanic fold light brown. Surface of throat and chest yellowish-brown with irregular dark brown and white patches and white and orange dots. Center of throat with black longitudinal band. Surface of abdomen white, mottled with orange dots and black patches. Surface of ventral limbs purple brown, with white mottling and dark-brown patches. Spines on tips of tubercles on ventral hindlimbs and area around cloaca black. Digits gray white; subarticular tubercles, inner and outer metacarpal tubercles and inner metatarsal tubercle grayish-brown. Pectoral glands and femoral glands white. Iris yellowish-brown with range mottling.

In preservative, the dorsal surface of the body is dark brown, with markings and patches more distinct. Surface of chest, throat and limbs are dark brown, with dark-brown markings and patches more distinct, white patches and dots faded and orange dots absent. Color of pectoral glands and femoral glands faded.

Variation. Morphometric variation is listed in Table 2. Most of the paratypes are similar to the holotype in morphology and color pattern, except for the following: tibio-tarsal articulation reaching forward to posterior corner of eye when hindlimb stretched along body in the holotype GEP a214, while reaching to shoulder in female paratype GEP a215; absence of nuptial pads and spines in the female paratype; larger body size in the female paratype.

Comparisons. *Boulenophrys lichun* sp. nov. can easily be distinguished from the following congeners by its heels not meeting when flexed hindlimbs held at right angles to body axis: *B. anlongensis*, *B. baishanzuensis*, *B. binlingensis*, *B. caudoprocta*, *B. cheni*, *B. chishuiensis*, *B. congjiangensis*, *B. daweimontis*, *B. fanjingmontis*, *B. fansipanensis*, *B. frigida*, *B. hoanglienensis*, *B. jiangi*, *B. jingdongensis*, *B. jinggangensis*, *B. jiulianensis*, *B. leishanensis*, *B. liboensis*, *B. lini*, *B. lushuiensis*, *B mirabilis*, *B. mufumontana*, *B. nanlingensis*, *B. omeimontis*, *B. palpebralespinosa*,

Table 2. Measurements (in mm) of voucher specimens of *Boulenophrys lichun* sp. nov.; * holotype.

Voucher	CIB 121428	GEP a211	GEP a212	GEP a213	GEP a214 *	GEP a215
Sex	male	male	male	male	male	female
SVL	36.7	33.5	35.7	34.6	37.0	47.1
HDL	13.1	12.7	13.5	12.9	13.3	15.3
HDW	13.6	13.3	13.8	13.6	13.9	16.5
ED	4.5	4.0	4.5	4.5	4.8	5.5
TD	2.3	2.6	2.5	2.5	2.6	2.8
TED	1.7	1.7	1.8	1.8	1.7	2.4
SNT	4.5	4.4	4.5	4.5	4.6	4.9
IND	3.6	3.7	3.8	3.7	3.9	4.3
IOD	3.5	3.3	3.4	3.5	3.7	4.3
HDN	8.7	7.8	8.7	9.1	9.2	10.2
RAD	8.6	7.0	8.5	8.1	8.7	9.0
FTL	20.7	18.9	20.7	20.9	21.4	24.1
TIB	14.3	12.5	14.3	14.5	14.7	15.7

B. qianbeiensis, *B. sangzhiensis*, *B. sanmingensis*, *B. shimentaina*, *B. shunhuangensis*, *B. spinata*, *B. sanmingensis*, *B. tongboensis*, *B. tuberogranulata*, *B. wuliangshanensis*, *B. xianjuensis*, *B. yangmingensis*, *B. yaoshanensis*, *B. yingdeensis* (vs. heels overlapping), from *B. binchuanensis*, *B. elongata*, *B. lishuiensis*, *B. minor*, *B. xiangnanensis*, *B. xuefengmontis* (vs. heels just meeting), and from *B. angka*, *B. daiyunensis*, *B. baolongensis*, *B. wushanensis*, *B. yunkaiensis* (vs. heels just meeting or slightly overlapping).

Boulenophrys lichun sp. nov. can easily be distinguished from the following congeners by its tongue not notched distally: *B. brachykolos*, *B. insularis*, *B. pepe* (vs. tongue notched distally). *Boulenophrys lichun* sp. nov. can easily be distinguished from the following congeners by its presence of vomerine teeth: *B. acuta*, *B. boettgeri*, *B. caobangensis*, *B. daoji*, *B. hungtai*, *B. hengshanensis*, *B. kuatunensis*, *B. ombrophila*, *B. obesa*, *B. shuichengensis*, *B. wugongensis* (vs. vomerine teeth absent).

Boulenophrys lichun sp. nov. can easily be distinguished from the following congeners by its absence of lateral fringes on webbing on toes: *B. dongguanensis*, *B. fengshunensis*, *B. nankunensis*, *B. puningensis* (vs. toes with rudimentary webbing), and from *B. rubrimera* (vs. toes with narrow lateral fringes).

Distribution and natural history. Currently, *Boulenophrys lichun* sp. nov. is only known from the coastal hills of Ningde City, eastern Fujian Province, China. It inhabits flowing montane seeps and the nearby forest floor and leaf litter. The habitat is surrounded by secondary forest mixed with bamboo groves at elevations between 150–510 m. Advertisement calls of males were heard from February to May. Males were found calling in rock crevices.

Discussion

The lack of follow-up surveys can pose issues in terms of endangered species listing. *Boulenophrys lichun* is currently only known from the coastal hills of Ningde City, eastern Fujian. The development of tourism infrastructure, stream diversion and tea leaf cultivation have gradually affected and threatened the habitats of the new species. Thus, more data (i.e., distribution, population size, potential and existing risk factors, etc.) from long-term extensive surveys are urgently required to make an assessment of their endangered status.

Boulenophrys possess limited dispersal abilities and narrow ecological niches, resulting in the restricted distribution ranges of many species (Wang et al. 2019a; Lyu et al. 2023). Their high levels of morphological conservatism (Liu et al. 2018; Wang et al. 2022; Lyu et al. 2023) and the lack of follow-up surveys have led to inadequate protection due to misidentifications and deficient data. Thus, we provide a provincial key below to aid the local authorities in accurately identifying species during field identifications and data collection efforts and further serve their conservation.

Key to *Boulenophrys* species occurring in Fujian Province, China

1 Vomerine ridges and vomerine teeth present **2**
– Vomerine ridges and vomerine teeth absent..... **3**
2 Toes with rudimentary webbing and wide lateral fringes ..... ***B. daiyunensis***
– Toes without webbing and lateral fringes..... ***B. lichun***
3 Toes with rudimentary webbing and lateral fringes **4**
– Toes without webbing and lateral fringes..... ***B. ombrophila***
4 Toes with wide lateral fringes..... **5**
– Toes with narrow lateral fringes ..... ***B. kuatunensis***
5 Round light patches on the shoulder present..... ***B. boettgeri***
– Round light patches on the shoulder absent..... ***B. sanmingensis***

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

References

Bonaparte CLJL (1850) Conspectus Systematum Herpetologiae et Amphibiologiae. Editio altera reformata [Lugduni Batavorum], Brill EJ, Leiden, 1 pp.

Bourret R (1937) Notes herpétologiques sur l'Indochine française. XIV. Les batraciens de la collection du Laboratoire des Sciences Naturelles de l'Université. Descriptions de quinze especes ou variétés nouvelles. Annexe au Bulletin Général de l'Instruction Publique. Hanoi 1937: 5–56.

Fei L, Ye CY (2016) Amphibians of China (Vol. 1). Science Press, Beijing, 1040 pp.

Fei L, Ye CY, Huang YZ (1983) Two new subspecies of *Megophrys omeimontis* Liu from China (Amphibia, Pelobatidae). Acta Herpetologica Sinica. New Series. Chengdu 2(2): 49–52. [In Chinese with English abstract]

Fei L, Hu SQ, Ye CY, Huang YZ (2009) Fauna Sinica. Amphibia. (Vol. 2). Anura. Science Press, Beijing, 503 pp. [in Chinese]

Frost DR (2024) Amphibian Species of the World: an online reference. Version 6.2. American Museum of Natural History, New York, USA. https://amphibiansoftheworld.amnh.org/index.php [accessed 9 September 2024]

Hu SQ, Zhao EM, Liu CC (1973) A survey of amphibians and reptiles in Kweichow province, including a herpetofaunal analysis. Acta Zoologica Sinica/ Dong wu xue bao, 19: 149–181.

Inger RF, Romer JD (1961) A new pelobatid frog of the genus *Megophrys* from Hong Kong. Fieldiana, Zoology, 39: 533–538.

Jiang JP, Ye CY, Fei L (2008) A new horn toad *Megophrys sangzhiensis* from Hunan, China (Amphibia, Anura). Zoological Research 29: 219–222. [in Chinese with English abstract] https://doi.org/10.3724/SP.J.1141.2008.00219

Lanfear R, Calcott B, Ho SYW, Guindon S (2012) PartitionFinder: combined selection of partitioning schemes and substitution models for phylogenetic analyses. Molecular Biology & Evolution 29: 1695–1701. https://doi.org/10.1093/molbev/mss020

Li YL, Jin MJ, Zhao J, Liu ZY, Wang YY, Pang H (2014) Description of two new species of the genus *Megophrys* (Amphibia: Anura: Megophryidae) from Heishiding Nature Reserve, Fengkai, Guangdong, China, based on molecular and morphological data. Zootaxa 3795: 449–471. https://doi.org/10.11646/zootaxa.3795.4.5

Li SZ, Xu N, Liu J, Jiang JP, Wei G, Wang B (2018) A new species of the asian toad genus *Megophrys* sensu lato (Amphibia: Anura: Megophryidae) from Guizhou Province, China. Asian Herpetological Research 9: 224–239. https://doi.org/10.16373/j.cnki.ahr.180072

Li SZ, Lu NN, Liu J, Wang B (2020) Description of a new *Megophrys* Kuhl & Van Hasselt, 1822 (Anura, Megophryidae) from Guizhou Province, China. ZooKeys 986: 101–126. https://doi.org/10.3897/zookeys.986.57119

Liu CC (1950) Amphibians of western China. Fieldiana. Zoology Memoires 2: 1–397. [+ 10 pl.] https://doi.org/10.5962/bhl.part.4737

Liu ZY, Chen GL, Zhu TQ, Zeng ZC, Lyu ZT, Wang J, Messenger K, Greenberg AJ, Guo ZX, Yang ZH, Shi SH, Wang YY (2018) Prevalence of cryptic species in morphologically uniform taxa – Fast speciation and evolutionary radiation in Asian frogs. Molecular Phylogenetics and Evolution 127: 723–731. https://doi.org/10.1016/j.ympev.2018.06.020

Liu J, Li S, Wei G, Xu N, Cheng Y, Wang B, Wu J (2020) A new species of the asian toad genus *Megophrys* sensu lato (Anura: Megophryidae) from Guizhou Province, China. Asian Herpetological Research 11: 1–18. https://doi.org/10.16373/j.cnki.ahr.190041

Luo T, Wang Y, Wang S, Lu X, Wang W, Deng H, Zhou J (2021) A species of the genus *Panophrys* (Anura, Megophryidae) from southeastern Guizhou Province, China. ZooKeys 1047(2):27–60. https://doi.org/10.3897/zookeys.1047.61097

Lyu ZT, Li YQ, Zeng ZC, Zhao J, Liu ZL, Guo GX, Wang YY (2020) Four new species of Asian horned toads (Anura, Megophryidae, *Megophrys*) from southern China. ZooKeys 942: 105–140. https://doi.org/10.3897/zookeys.942.47983

Lyu ZT, Zeng ZC, Wang J, Liu ZY, Huang YQ, Li WZ, Wang YY (2021) Four new species of *Panophrys* (Anura, Megophryidae) from eastern China, with discussion on the recognition of *Panophrys* as a distinct genus. Zootaxa 4927(1):9–40. https://doi.org/10.11646/zootaxa.4927.1.2

Lyu ZT, Qi S, Wang J, Zhang SY, Zhao J, Zeng ZC, Wan H, Yang JH, Mo YM, Wang YY (2023) Generic classification of Asian Horned Toads (Anura: Megophryidae: Megophryinae) and monograph of Chinese species. Zoological Research. Kunming 44: 380–450. https://doi.org/10.24272/j.issn.2095-8137.2022.372

Messenger KR, Dahn HA, Liang Y, Xie P, Wang Y, Lu C (2019) A new species of the genus *Megophrys* Gunther, 1864 (Amphibia: Anura: Megophryidae) from Mount Wuyi, China. Zootaxa 4554: 561–583. https://doi.org/10.11646/zootaxa.4554.2.9

Mo XY, Shen YH, Li HH, Wu XS (2010) A new species of *Megophrys* (Amphibia: Anura: Megophryidae) from the northwestern Hunan Province, China. Current Zoology 56(4): 432–436. https://doi.org/10.1093/czoolo/56.4.432

Nguyen TQ, Pham CT, Nguyen TT, Luong AM, Ziegler T (2020) A new species of *Megophrys* (Amphibia: Anura: Megophryidae) from Vietnam. Zootaxa 4722(5): 401–422. https://doi.org/10.11646/zootaxa.4722.5.1

Pope CH (1929) Four new frogs from Fukien Province, China. American Museum Novitates 352: 1–5.

Qi S, Lyu ZT, Wang J, Mo YM, Zeng ZC, Zeng YJ, Dai KY, Li YQ, Grismer LL, Wang YY (2021) Three new species of the genus *Boulenophrys* (Anura, Megophryidae) from southern China. Zootaxa 5072 (5): 401–438. https://doi.org/10.11646/zootaxa.5072.5.1

Qian TY, Hu K, Mo XY, Gao Z, Zhang N, Yang DD (2023) A new species of *Boulenophrys* from central Hunan Province, China (Anura: Megophryidae). Vertebrate Zoology 73: 915–930. https://doi.org/10.3897/vz.73.e100889

Rao DQ, Yang DT (1997) The karyotypes of Megophryinae (Pelobatinae) with a discussion on their classification and phylogenetic relationships. Asiatic Herpetological Research 7: 93–102. https://doi.org/10.5962/bhl.part.18858

Ronquist F, Teslenko M, Van Der Mark P, Ayres D, Darling A, Höhna S, Larget B, Liu L, Suchard MA, Huelsenbeck JP (2012) Mrbayes 3.2: Efficient bayesian phylogenetic

inference and model choice across a large model space. Systematic Biology 61(3): 539–542. https://doi.org/10.1093/sysbio/sys029

Shen YH (1994) A new pelobatid toad of the genus *Megophrys* from China (Anura: Pelobatidae). Collection of Articles for the 60th Anniversary of the Foundation of the Zoological Society of China. Nanking, Zoological Society of China, 603–606.

Shi SC, Li DH, Zhu WB, Jiang W, Jiang JP, Wang B (2021) Description of a new toad of *Megophrys* Kuhl & Van Hasselt, 1822 (Amphibia: Anura: Megophryidae) from western Yunnan Province, China. Zootaxa 4942: 351–381. https://doi.org/10.11646/zootaxa.4942.3.3

Silvestro D, Michalak I (2012) raxmlGUI: A graphical front-end for RAxML. Organisms, Diversity & Evolution 12(4): 335–337. https://doi.org/10.1007/s13127-011-0056-0

Su HJ, Shi SC, Wu YQ, Li GR, Yao XG, Wang B, Li SZ (2020) Description of a new horned toad of *Megophrys* Kuhl & Van Hasselt, 1822 (Anura, Megophryidae) from southwest China. Zookeys 974: 131–159. https://doi.org/10.3897/zookeys.974.56070

Tapley B, Cutajar T, Mahony S, Nguyen CT, Dau VQ, Nguyen TT, Luong HV, Rowley JJL (2017) The Vietnamese population of *Megophrys kuatunensis* (Amphibia: Megophryidae) represents a new species of Asian horned frog from Vietnam and southern China. Zootaxa 4344: 465–492. https://doi.org/10.11646/zootaxa.4344.3.3

Tapley B, Cutajar TP, Mahony S, Nguyen CT, Dau VQ, Luong AM, Le DT, Nguyen TT, Nguyen TQ, Portway C, Luong HV, Rowley JJL (2018a) Two new and potentially highly threatened *Megophrys* Horned frogs (Amphibia: Megophryidae) from Indochina' s highest mountains. Zootaxa 4508: 301–333. https://doi.org/10.11646/zootaxa.4508.3.1

Tapley B, Cutajar T, Nguyen LT, Nguyen CT, Harding L, Portway C, Van Luong H, Rowley JJ (2018b) A new locality and elevation extension for *Megophrys rubrimera* (Tapley et al., 2017) in Bat Xat Nature Reserve, Lao Cai Province, northern Vietnam. Herpetology Notes 11: 865–868.

Tapley B, Cutajar T, Nguyen LT, Portway C, Mahony S, Nguyen CT, Harding L, Luong HV, Rowley JJL (2021) A new potentially Endangered species of *Megophrys* (Amphibia: Megophryidae) from Mount Ky Quan San, north-west Vietnam. Journal of Natural History 54: 2543–2575. https://doi.org/10.1080/00222933.2020.1856952

Thompson JD, Gibson TJ, Plewniak F, Jeanmougin F, Higgins DG (1997) The CLUSTAL_X windows interface: flexible strategies for multiple sequence alignment aided by quality analysis tools. Nucleic Acids Research 25: 4876–4882. https://doi.org/10.1093/nar/25.24.4876

Tian YZ, Sun A (1995) A new species of *Megophrys* from China (Amphibia: Pelobatidae). Journal of Liupanshui Teachers College 52(3): 11–15. [in Chinese]

Tian YZ, Gu XM, Sun AQ (2000) A new species of *Megophrys* in China (Amphibia: Pelobatidae). Acta Zootaxonomica Sinica 25: 462–466. [in Chinese]

Wang YY, Zhang TD, Zhao J, Sung YH, Yang JH, Pang H, Zhang Z (2012) Description of a new species of the genus *Xenophrys* Gunther, 1864 (Amphibia: Anura: Megophryidae) from Mount Jinggang, China, based on molecular and morphological data. Zootaxa 3546: 53–67. https://doi.org/10.11646/zootaxa.3546.1.4

Wang YY, Zhao J, Yang JH, Zhou Z, Chen GL, Liu Y (2014) Morphology, molecular genetics, and bioacoustics support two new sympatric *Xenophrys* toads (Amphibia: Anura: Megophryidae) in Southeast China. PloS ONE 9: e93075. https://doi.org/10.1371/journal.pone.0093075

Wang J, Liu ZY, Lyu ZT, Zeng ZC, Wang YY (2017a) A new species of the genus *Xenophrys* (Amphibia: Anura: Megophryidae) from an offshore island in Guangdong Province, southeastern China. Zootaxa 4324: 541–556. https://doi.org/10.11646/zootaxa.4324.3.8

Wang YF, Liu BQ, Jiang K, Jin W, Xu JN, Wu CH (2017b) A new species of the Horn Toad of the genus *Xenophrys* from Zhejiang, China (Amphibia: Megophryidae). Chinese Journal of Zoology 52: 19–29. [in Chinese with English abstract] https://doi.org/10.13859/j.cjz.201701003

Wang J, Lyu ZT, Liu ZY, Liao CK, Zeng ZC, Zhao J, Li YL, Wang YY (2019a) Description of six new species of the subgenus *Panophrys* within the genus *Megophrys* (Anura, Megophryidae) from southeastern China based on molecular and morphological data. ZooKeys 851: 113–164. https://doi.org/10.3897/zookeys.851.29107

Wang L, Deng X, Liu Y, Wu Q, Liu Z (2019b) A new species of the genus *Megophrys* (Amphibia: Anura: Megophryidae) from Hunan, China. Zootaxa 4695: 301–330. https://doi.org/10.11646/zootaxa.4695.4.1

Wang B, Wu YQ, Peng JW, Shi SC, Lu NN, Wu J (2020) A new *Megophrys* Kuhl & Van Hasselt (Amphibia, Megophryidae) from southeastern China. ZooKeys 904: 35–62. https://doi.org/10.3897/zookeys.904.47354

Wang J, Zeng ZC, Lyu ZT, Qi S, Liu ZY, Chen HH, Lu YH, Xiao HW, Lin CR, Chen K, Wang YY (2022) Description of three new *Boulenophrys* species from eastern Guangdong, China, emphasizing the urgency of ecological conservation in this region (Anura, Megophryidae). Zootaxa 5099(1): 91–119. https://doi.org/10.11646/zootaxa.5099.1.4

Wang J, Lin SS, Gan JS, Chen HH, Yu LM, Pan Z, Xiao JJ, Zeng ZC (2024) A new species of the genus *Boulenophrys* from South China (Anura, Megophryidae). Zootaxa 5514(5): 451–468. https://doi.org/10.11646/zootaxa.5514.5.3

Wu YH, Suwannapoom C, Poyarkov NA, Chen JM, Pawangkhanant P, Xu K, Jin JQ, Murphy RW, Che J (2019) A new species of the genus *Xenophrys* (Anura: Megophryidae) from northern Thailand. Zoological Research 40: 564–574. https://doi.org/10.24272/j.issn.2095-8137.2019.032

Wu YQ, Li SZ, Liu W, Wang B, Wu J (2020) Description of a new horned toad of *Megophrys* Kuhl & Van Hasselt, 1822 (Amphibia, Megophryidae) from Zhejiang Province, China. ZooKeys 1005: 73–102. https://doi.org/10.3897/zookeys.1005.58629

Xu N, Li SZ, Liu J, Wei G, Wang B (2020) A new species of the horned toad *Megophrys* Kuhl & Van Hasselt, 1822 (Anura, Megophryidae) from southwest China. ZooKeys 943: 119–144. https://doi.org/10.3897/zookeys.943.50343

Ye CY, Fei L (1995) Taxonomic studies on the small type *Megophrys* in China including descriptions of the new species (subspecies) (Peloatidae: genus *Megophrys*). Acta Herpetologica Sinica 4–5: 72–81. [in Chinese]

Ye CY, Fei L, Xie F (2007) A new species of Megophryidae – *Megophrys baolongensis* from China (Amphibia, Anura). Herpetologica Sinica 11: 38–41. [in Chinese]

Zeng ZC, Wang J, Chen HH, Xiao WW, Zhan BB, Li YH, Lin SS (2024) A new species of the genus *Boulenophrys* (Anura, Megophryidae) from eastern Guangdong, China. Asian Herpetological Research 15(1): 12–21.

Zhang Y, Li G, Xiao N, Li J, Pan T, Wang H, Zhang B, Zhou J (2017) A new species of the genus *Xenophrys* (Amphibia: Anura: Megophryidae) from Libo County, Guizhou, China. Asian Herpetological Research 8: 75–85. https://doi.org/10.16373/j.cnki.ahr.160041

Supplementary material 1

Localities, voucher information, and GenBank accession numbers for all samples used in this study

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Data type: xlsx

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